ILRS SLR MISSION SUPPORT REQUEST FORM (January 2009)

SECTION I: MISSION INFORMATION:

General Information:

Satellite Name: *LARES (LAser Relativity Satellite)*

Satellite Host Organization: *Italian Space Agency, ASI*

Web Address: *www.asi.it*

Contact Information:

Primary Technical Contact Information:

Name: *Prof. Antonio Paolozzi*

Address: *Dip. Ingegneria Aerospaziale Elettrica Energetica "Sapienza Università di Roma", Via Salaria 851, Roma, ITALY*

Phone No.: *(+39) 06 49919769*

Fax No.: *(+39) 06 49919768*

E-mail Address: *antonio.paolozzi@uniroma1.it*

Alternate Technical Contact Information:

Name: *Dr. Giampiero Sindoni*

Address: *Dip. Ingegneria Aerospaziale Elettrica Energetica, "Sapienza Università di Roma", Via Salaria 851, Roma, ITALY*

Phone No.: *(39) 06 4919767*

Fax No.: *(39) 06 4919768*

E-mail Address: *giampiero.sindoni@uniroma1.it*

Primary Science Contact Information:

Name: *Prof. Ignazio Ciufolini*

Address: *Dip. Ingegneria dell'innovazione, Università del Salento, Via Monteroni , 73100 Lecce, ITALY*

Phone No.: *(39) 380 3070772*

Fax No.:

E-mail Address: *ignazio.ciufolini@gmail.com* , *ignazio.ciufolini@unisalento.it*

Alternate Science Contact Information:

Name: *Prof. Enrico Flamini*

Address: *viale Liegi 26, 00198 Roma, ITALY*

Phone No.: *+39) 06 85671*

Fax No.: *(+39) 06 85671*

E-mail Address: *enrico.flamini@asi.it*

Mission Specifics:

Scientific or Engineering Objectives of Mission:

LARES will achieve important measurements in gravitational physics, General Relativity, space geodesy and geodynamics, in particular, together with the LAGEOS and LAGEOS 2 satellites and with the GRACE models, it will provide a very accurate determination of the Earth gravitomagnetic field and of the Lense-Thirring effect.

Satellite Laser Ranging (SLR) Role of Mission: *Key Role*

Anticipated Launch Date: *December 2011*

Expected Mission Duration: *Decades*

Orbital Accuracy Required: *< 1 cm CEP for weekly arc*

Anticipated Orbital Parameters:

Altitude: *1450 km*

Inclination: *71.5 degrees*

Eccentricity: *nearly zero*

Orbital Period: *5500 s*

Frequency of Orbital Maneuvers: *N.A.*

Mission Timeline: *N.A.*

Tracking Requirements:

Tracking Schedule: *Above BLITS*

Spatial Coverage: *Global*

Temporal Coverage: *Daily tracking*

Operations Requirements:

Prediction Center: *Sapienza Università di Roma*

Prediction Technical Contact Information

Name: *Prof. Ignazio Ciufolini*

Address: *Dip. Ingegneria dell'Innovazione, Università del Salento,*

Via Monteroni , 73100 Lecce, ITALY

Phone No.: *(39) 380 3070772*

Fax No.:

E-mail Address: *ignazio.ciufolini@gmail.com , ignazio.ciufolini@unisalento.it*

Priority of SLR for POD: *No. 1 (and only)*

Other Sources of POD (GPS, Doppler, etc.): *None*

Normal Point Time Span (sec): *30 sec.*

Tracking Network Required (Full/NASA/EUROLAS/WPLTN/Mission Specific): *Full*

SECTION II: TRACKING RESTRICTIONS:

Several types of tracking restrictions have been required during some satellite missions. See *http://ilrs.gsfc.nasa.gov/satellite_missions/restricted.html* for a complete discussion.

1) Elevation restrictions: Certain satellites have a risk of possible damage when ranged near the zenith. Therefore a mission may want to set an elevation (in degrees) above which a station may not range to the satellite.

2) Go/No-go restrictions: There are situations when on-board detectors on certain satellites are vulnerable to damaged by intense laser irradiation. These situations could include safe hold position or maneuvers. A small ASCII file is kept on a computer controlled by the satellite's mission which includes various information and the literal "go" or "nogo" to indicate whether it is safe to range to the spacecraft. Stations access this file by ftp every 5-15

minutes (as specified by the mission) and do not range when the flag file is set to “nogo” or when the internet connection prevents reading the file.

3) Segment restrictions: Certain satellites can allow ranging only during certain parts of the pass as seen from the ground. These missions provide station-dependent files with lists of start and stop times for ranging during each pass.

4) Power limits: There are certain missions for which the laser transmit power must always be restricted to prevent detector damage. This requires setting laser power and beam divergence at the ranging station before and after each pass. While the above restrictions are controlled by software, this restriction is often controlled manually. Many ILRS stations support some or all of these tracking restrictions. See xxx for the current list. You may wish to work through the ILRS with the stations to test their compliance with your restrictions or to encourage additional stations that are critical to your mission to implement them.

The following information gives the ILRS a better idea of the mission's restrictions. Be aware that once predictions are provided to the stations, there is no guarantee that forgotten restrictions can be immediately enforced. Can detector(s) or other equipment on the spacecraft be damaged or confused by excessive irradiation, particularly in any one of these wavelengths (532nm, 1064nm, 846nm, or 423nm)? *NO.*

Are there times when the LRAs will not be accessible from the ground? *NO.*

(If so, go/nogo or segmentation files might be used to avoid ranging an LRA that is not accessible.)

Is there a need for an altitude tracking restriction? *NO.*

Is there a need for a go/no-go tracking restriction? *NO.*

Is there a need for a pass segmentation restriction? *NO.*

Is there a need for a laser power restriction? *NO.*

What power level (mW/cm_2)? Is manual control of transmit power acceptable? N/A

For ILRS stations to range to satellites with restrictions, the mission sponsor must agree to the following statement:

“The mission sponsor agrees not to make any claims against the station or station contractors or subcontractors, or their respective employees for any damage arising from these ranging activities, whether such damage is caused by negligence or otherwise, except in the case of willful misconduct.”

Please initial here to express agreement:

Other comments on tracking restrictions: *NONE*

SECTION III: RETROREFLECTOR ARRAY INFORMATION:

A prerequisite for accurate reduction of laser range observations is a complete set of pre-launch parameters that define the characteristics and location of the LRA on the satellite. The set of parameters should include a general description of the array, including references to any ground-tests that may have been carried out, array manufacturer and whether the array type has been used in previous satellite missions. So the following information is requested:

Retroreflector Primary Contact Information:

Name: *Ing. Claudio Paris*

Address: *Dip. Ingegneria .Aerospaziale Elettrica Energetica "Sapienza Università di Roma", Via Salaria 851, Roma, ITALY*

Phone No.: *(+39) 06 4919767*

Fax No.: *(+39) 06 4919767*

E-mail Address: *claudio.paris@uniroma1.it*

Array type (spherical, hexagonal, planar, etc.), to include a diagram or photograph:

Spherical type.

Array manufacturer:

Carl Zeiss Inc.

Link (URL or reference) to any ground-tests that were carried out on the array:

www.lares-mission.com/FFDP.pdf

The LRA design and/or type of cubes was previously used on the following missions:

The design of the CCRs and relevant mounting system has been inspired starting from the CCRs design of both LAGEOS1 and LAGEOS2.

For accurate orbital analysis it is essential that full information is available in order that a model of the 3-dimensional position of the satellite center of mass may be referred to the location in space at which the laser range measurements are made. To achieve this, the 3-D location of the LRA phase center must be specified in a satellite fixed reference frame with respect to the satellite's mass center. In practice this means that the following parameters must be available at mm accuracy or better: The 3-D location (possibly time-dependent) of the satellite's mass center relative to a satellite-based origin:

LARES satellite has been designed as a sphere fully covered by CCRs. Tolerance between CoG and geometrical center of the satellite is of 0.2 mm; the sphere has a 0.05 mm sphericity tolerance.

The 3-D location of the phase center of the LRA relative to a satellite-based origin:

However, in order to achieve the above if it is not directly specified (the ideal case) by the satellite manufacturer, and as an independent check, the following information must be supplied prior to launch: The position and orientation of the LRA reference point (LRA mass-center or marker on LRA assembly) relative to a satellite-based origin:The position (XYZ) of either the vertex or the center of the front face of each corner cube within the LRA assembly, with respect to the LRA reference point and including information of amount of recession of front faces of cubes:

Recess of the front faces from the spherical surface is 2.6 +0.1/-0.2 mm, so the nominal distance of the front face from the geometrical center is 179.4 mm nominally.

The orientation of each cube within the LRA assembly (three angles for each cube):

CCRs rows position:

ROW	*#CCR*	*Latitude [deg]*	*Angolar Distance 1*	*Longitude from *X*
I	*1*	*90.00*	*…*	*…*
II	*5*	*70.00*	*72.00*	*0*
III	*10*	*50.00*	*36.00*	*23*
IV	*14*	*30.00*	*25.714*	*0*
V	*16*	*10.00*	*22.50*	*11.25*
-V	*16*	*-10.00*	*22.50*	*11.25*
-IV	*14*	*-30.00*	*25.714*	*0*
-III	*10*	*-50.00*	*36.00*	*23*
-II	*5*	*-70.00*	*72*	*0*
-I	*1*	*-90.00*	*…*	*…*

CCRs Azimuth.

Starting from the polar cavity, the first cavity of each row has to rotate 23° about its longitudinal axis and with respect to the first cavity of the previous row. On each row, each CCR, moving clockwise from the first one, has to rotate 23 deg with respect to the previous one. On row V (and -V) the first cavity has to rotate 45° from the horizontal plane, for mechanical reasons, then the following CCRs are rotated by the sequence +90°, +30°, 90°, +30°, and so on. The table shows the absolute value s of the rotation angle for each cavity, starting from the polar.

Rows \ Cavities	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15	#16
I	*0*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
II	*23*	*46*	*69*	*92*	*115*	---	---	---	---	---	---	---	---	---	---	---
III	*46*	*69*	*92*	*115*	*138*	*161*	*184*	*207*	*230*	*253*	---	---	---	---	---	---
IV	*69*	*92*	*115*	*138*	*161*	*184*	*207*	*230*	*253*	*276*	*299*	*322*	*345*	*368*	---	---
V	*45*	*135*	*165*	*255*	*285*	*15*	*45*	*135*	*165*	*255*	*285*	*15*	*45*	*135*	*165*	*255*

The table represents only the northern hemisphere, the southern one is a mirror image of the latter.

The shape and size of each corner cube, especially the height:

The front face is circular with tabs for mounting. Height: 27.889 mm. Diameter: 38.10 mm. Diameter (with tabs): 41.15 mm.

The material from which the cubes are manufactured (e.g. quartz):

Suprasil 31.

The refractive index of the cube material, as a function of wavelength λ (micron):

n = 1.45637 @ 656.3 nm

n = 1.45846 @ 587.6 nm

n = 1.46313 @ 486.1 nm

n = 1.46669 @ 435.8 nm

n = 1.50855 @ 248 nm

Dihedral angle offset(s) and manufacturing tolerance:

1.5°± 0.5°.

Radius of curvature of front surfaces of cubes, if applicable:

0

Flatness of cubes' surfaces (as a fraction of wavelength):

Back faces, *λ/10; front face λ/8.Exiting wavefront λ/4.*

Whether or not the cubes are coated and with what material:

Not coated.

Other Comments: //

An example of the metric information for the array position that should be supplied is given schematically below for the LRA on the GIOVE-A satellite. Given the positions and characteristics of the cubes within the LRA tray, it is possible to compute the location of the array phase center. Then given the **C** and **L** vectors it is straightforward to calculate the vector from the satellite's center of mass (CoM) in a spacecraft-fixed frame to the LRA phase center. Further analysis to derive the array farfield diffraction patterns will be possible using the information given above.

A good example of a well-specified LRA is that prepared by GFZ for the CHAMP mission in the *paper "The Retro-Reflector for the CHAMP Satellite: Final Design and Realization", which is* available on the ILRS Web site at *http://ilrs.gsfc.nasa.gov/docs/rra_champ.pdf* .

The final and possibly most complex piece of information is a description (for an active satellite) of the satellite's attitude regime as a function of time, which must be supplied in some form by the operating agency. This algorithm will relate the spacecraft reference frame to, for example, an inertial frame such as J2000.

RETROREFLECTOR ARRAY REFERENCES

Two reports, both by David Arnold, are of particular interest in the design and analysis of laser retroreflector arrays.

Method of Calculating Retroreflector-array Transfer Functions, David A. Arnold, Smithsonian Astrophysical Observatory Special Report 382, 1979.

Retroreflector Array Transfer Functions, David A. Arnold, ILRS Signal Processing Working Group, 2002. Paper available at *http://nercslr.nmt.ac.uk/sig/signature.html* .

SECTION IV: MISSION CONCURRENCE

As an authorized representative of the *LARES* mission, I

hereby request and authorize the ILRS to track the satellite described in this document.

Name (print): TBD Date ______________________________

Signature____

Position:

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Send form to: ILRS Central Bureau
c/o Carey Noll
NASA GSFC
Code 690
Greenbelt, MD 20771
USA
301-614-6542 (Voice)
301-614-6015 (Fax)
Carey.Noll@nasa.gov